Acoustic Monitoring Provides First Records of Hoary Bats (*Lasiurus cinereus*) and Delineates the Distribution of Silver-Haired Bats (*Lasionycteris noctivagans*) in Southeast Alaska

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ACOUSTIC MONITORING PROVIDES FIRST RECORDS OF HOARY BATS (*LASIURUS CINEREUS*) AND DELINEATES THE DISTRIBUTION OF SILVER-HAIRED BATS (*LASIONYCTERIS NOCTIVAGANS*) IN SOUTHEAST ALASKA

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ABSTRACT—Although 5 species of bats have been documented in Southeast Alaska, information on species not of the genus *Myotis* is derived solely from 4 specimens of the Silver-haired Bat (*Lasionycteris noctivagans*). We acoustically monitored for bat species that produce low frequency echolocation calls (<30 kHz minimum frequency), specifically Hoary Bat (*Lasiurus cinereus*), Silver-haired Bat, and Big Brown Bat (*Eptesicus fuscus*) at 40 sites in 16 locations across Southeast Alaska from 2011 to 2013 using passive bat detectors. The Hoary Bat was not previously known from Alaska, but we recorded 25 call files of this species (of 26,151 low frequency bat files) at 5 sites in northern Southeast Alaska (4 mainland sites and 1 site on Chichagof Island); an additional 110 call files were classified as probable Hoary Bat, but were ambiguous. We recorded 3075 call files that contained echolocation calls diagnostic of Silver-haired Bats; no files had characteristics diagnostic of Big Brown Bats. The rest of the low frequency recordings were identified as probable Silver-haired Bat calls, although Big Brown Bats cannot be ruled out due to the extensive overlap of acoustic characteristics between these 2 species. We recorded Hoary Bats almost exclusively during the autumn migration period. By contrast, Silver-haired Bats were detected throughout the summer active season, indicating at least some individuals are resident in Southeast Alaska. Silver-haired Bat activity was greatest at sites on or near the mainland, with most sites showing peaks of activity in spring, suggesting bats from the interior may be overwintering in the region. Winter recordings suggest Silver-haired Bats (and Big Brown Bats if present) are active to some extent during winter in Southeast Alaska. Understanding the distribution and seasonality of Hoary and Silver-haired Bat activity in Southeast Alaska is a critical 1st step toward identifying their habitat requirements and conservation needs in this region.

Key words: acoustic monitoring, bats, Big Brown Bat, *Eptesicus fuscus*, Hoary Bat, *Lasionycteris noctivagans*, *Lasiurus cinereus*, Silver-haired Bat, Southeast Alaska

Until recently, only 6 species of bats were documented in Alaska. The Little Brown Myotis (*Myotis lucifugus*) is the most abundant and widely distributed bat in Alaska and the only species regularly found north of the panhandle (Parker and others 1997; Tessler and others 2014). Although a single specimen of Big Brown Bat (*Eptesicus fuscus*) was collected in 1955 along the Richardson Highway near Delta Junction, it is unclear whether it was a migrant or was unintentionally transported along the Alaska Highway (Reeder 1965). The 1st study to examine the distribution of bats in Alaska documented 4 species in Southeast Alaska in addition to the Little Brown Myotis: California Myotis (*M. californicus*); Keen's Myotis (*M. keenii);* Long-legged Myotis (*M. volans*); and Silver-haired Bat (*Lasionycteris noctivagans*) (Parker and others 1997). Of those 4 species, only a single specimen of Silver-haired Bat was documented on the mainland and only the Long-legged Myotis was found north of Wrangell Island (Parker and others 1997). Capture surveys conducted in 2005 extended the ranges of both Keen's and California Myotis northward by 300 km, to the mainland near Juneau (Boland and others 2009), but to date most of Southeast Alaska remains unsurveyed. The recent discovery of a 7th species, the morphologically cryptic Yuma Myotis (*M. yumanensis*), from several locations in the extreme southeastern corner of Southeast Alaska (Olson and others 2014), highlights the need for additional survey efforts to fully establish both the distribution and species diversity of bats across the region.

Trapping efforts across Southeast Alaska have so far captured only *Myotis* species (West 1991; West and Swain 1993; West 1994; Parker and others 1997; West and Swain 1999; Boland and others 2009). However, the Silver-haired Bat, based on 4 museum specimens (all female) collected in and around human residences during winter, is known to occur in Southeast Alaska (Parker and others 1997). One record was from the mainland along a transboundary river (Taku River), and 3 were from islands of the Alexander Archipelago (Wrangell, Mitkof, and Revillagigedo). Boland and others (2009) reported a close-range (1.5 m) visual observation of a Silver-haired Bat on Prince of Wales Island, the 1st report of this species in Southeast Alaska during summer. That study also recorded possible echolocation calls of Silver-haired Bats from Juneau, Prince of Wales Island, and Wrangell Island, but the calls could not be positively distinguished from those of Big Brown Bats (Boland and others 2009).

Based on their presence on Vancouver Island and the southern coast of British Columbia (Ministry of Environment 2008a, 2008b), both the Hoary and Big Brown Bat also potentially occur in Southeast Alaska. The Hoary Bat is one of the most widespread bat species in North America, with a range that extends from northeastern Canada to South America (Shump and Shump 1982). Hoary Bats are migratory and known to travel long distances (Cryan and others 2004). They have been found within 400 to 500 km of the Alaskan border in northern, central, and south coastal British Columbia (Ministry of Environment 2008b), and have also been detected acoustically in the Yukon (Slough and others 2014). Nearest records of the Big Brown Bat in British Columbia are 2 live captures near Owen Lake, <300 km southeast of the Alaskan border, suggesting this species may also be found in Southeast Alaska (Ministry of Environment 2008a).

Acoustic monitoring is a valuable complement to ground-based capture techniques for documenting species diversity, particularly for rare, uncommon, and high-flying species that have unique echolocation calls (O'Farrell and Gannon 1999). Although bat species with low frequency calls (<30 kHz minimum frequency; Big Brown Bat, Hoary Bat, and Silver-haired Bat) have not been captured in Southeast Alaska, their calls are easily distinguished from those of *Myotis* species, making acoustic monitoring a useful tool for documenting their presence. We used acoustic monitoring data to investigate the presence, distribution, and seasonal activity patterns of Silver-haired Bats, Big Brown Bats, and Hoary Bats in Southeast Alaska. Our objectives were: (1) to determine the presence and distribution of Silver-haired Bats, Big Brown Bats, and Hoary Bats in Southeast Alaska during the summer active season (April–November); (2) examine if the species detected are resident in Southeast Alaska or migrating through the region; and (3) examine if any of these species overwinter in Southeast Alaska.

METHODS

Study Sites

Southeast Alaska is the panhandle region of Alaska, extending from Yakutat Bay in the north to Dixon Entrance in the south. The region is composed of the Alexander Archipelago and a narrow strip of mainland, and is bordered by the rugged Coast Ranges to the east and the Pacific Ocean to the west. The Coast Ranges, with their associated glaciers and icefields, form a barrier between Southeast Alaska and the Canadian interior that is dissected by several transboundary rivers, which provide connectivity between the coast and interior. The mountains interact with the warm currents of the Pacific Ocean to create a maritime climate with cool, wet summers and relatively mild, wet winters. Winter (December–February) temperatures average 1.4°C on the Juneau mainland and 2.6°C on the outer coast in

Sitka; the average temperature during the midsummer months (May–August) are similar throughout the region at 12.2°C (National Climatic Data Center 2013). Monthly precipitation during the driest months (April–July) ranges from 9.0 cm in Juneau to 19.5 cm in Ketchikan, and approximately doubles during the wettest months (September–January). The region is a coastal temperate rainforest dominated by Sitka Spruce (*Picea sitchensis*) and Western Hemlock (*Tsuga heterophylla*). The few human settlements in the region are located primarily at low elevations near the coast. Roads are also few and localized, with the most extensive road systems occurring in areas of intensive timber harvest, including Prince of Wales and surrounding islands in the south and Chichagof Island in the north.

We deployed bat detectors at 16 locations across Southeast Alaska that covered most of the larger communities in the region (Fig. 1). Two locations were monitored at multiple sites; Juneau (n = 22) and Sitka (n = 4) (Fig. 1). All sites were located at elevations <50 m except for 3 in Juneau (Dan Moller Trail, 343 m; Salmon Creek Dam, 369 m; and Perseverance, 218 m). Most sites were accessed by road or trail; 3 detectors along transboundary rivers (the Alsek, Taku, and Stikine) and 1 at Hugh Smith Lake were accessed by boat or floatplane. Thirty sites were located near freshwater features (lakes, rivers, streams, ponds, and wetlands); 2 in residential areas; 4 along beaches; and 4 in forest gaps or along forest edges (Appendix).

Acoustic Monitoring

We used a mix of AnaBat (SD2, Titley Scientific, Columbia, MO) and SongMeter2 (SM2BAT and SM2BAT+, Wildlife Acoustics, Concord, MA) detectors. Detectors were set with the microphone approximately 1.4 m above the ground, and all microphones were shielded from the weather with a plastic rain guard. We attached hygrochron iButtons (DS1923, Maxim Integrated, San Jose, CA) to the bottom of each detector to record temperature and relative humidity at the site at hourly intervals. We determined the temperature at which winter flight activity occurred by taking the measurement closest to the time at which the bat call was detected. Detectors were programmed to record nightly from dusk to dawn. For the purposes of this study we define 2 monitoring seasons: the winter hibernation season (December–March) and the summer active season (April–November). We defined the seasons in this way to ensure that winter detections represented overwintering bats rather than migrants.

We monitored a total of 22 sites in Juneau between March 2011 and December 2013 (''Juneau'' sites; Fig. 1, Table 1). Detectors were operated year-round for the 1st year to investigate winter activity of bats. In December 2012, 5 detectors were moved from sites that did not detect any bats the previous winter to new, alternate winter sites; these detectors were returned to their original monitoring sites in spring 2013. Beginning in December 2011, we deployed detectors at 18 other mainland, island, and transboundary river sites in 15 locations across Southeast Alaska (''region'' sites; Fig. 1). We monitored 8 region sites only during the summer active season and 10 region sites for at least part of both seasons (Appendix).

Analysis

We automatically isolated low frequency (<30 kHz minimum frequency; Big Brown Bat, Silver-haired Bat, or Hoary Bat) bat files from noise files and call files of other bat species on a computer using a combination of Kaleidoscope-Pro (Version 0.2.0, Wildlife Acoustics, Concord, MA) and custom-made filters in AnalookW (3.9c, 8 May 2013, copyright C Corben, Columbia, MO). Call files containing bat echolocation call sequences were passed through a second series of custom-made filters in AnalookW (see below) to identify the calls to species when possible (Silver-haired Bat ''LANO'', Big Brown Bat ''EPFU'', or Hoary Bat ''LACI''). Not all call files could be identified to species due to overlap in characteristics of certain call types between some species, poor call quality, the presence of multiple bats, or a combination of these factors. Those files were placed into 1 of 2 species groups: ''LANO-EPFU'' (either Silver-haired Bat or Big Brown Bat) or ''LowF'' (unidentified low frequency bat). All calls that passed the species filters were confirmed manually by one of the authors (CLL), who has extensive experience analyzing bat echolocation data.

Silver-haired Bats and Big Brown Bats frequently overlap in their search call parameters,

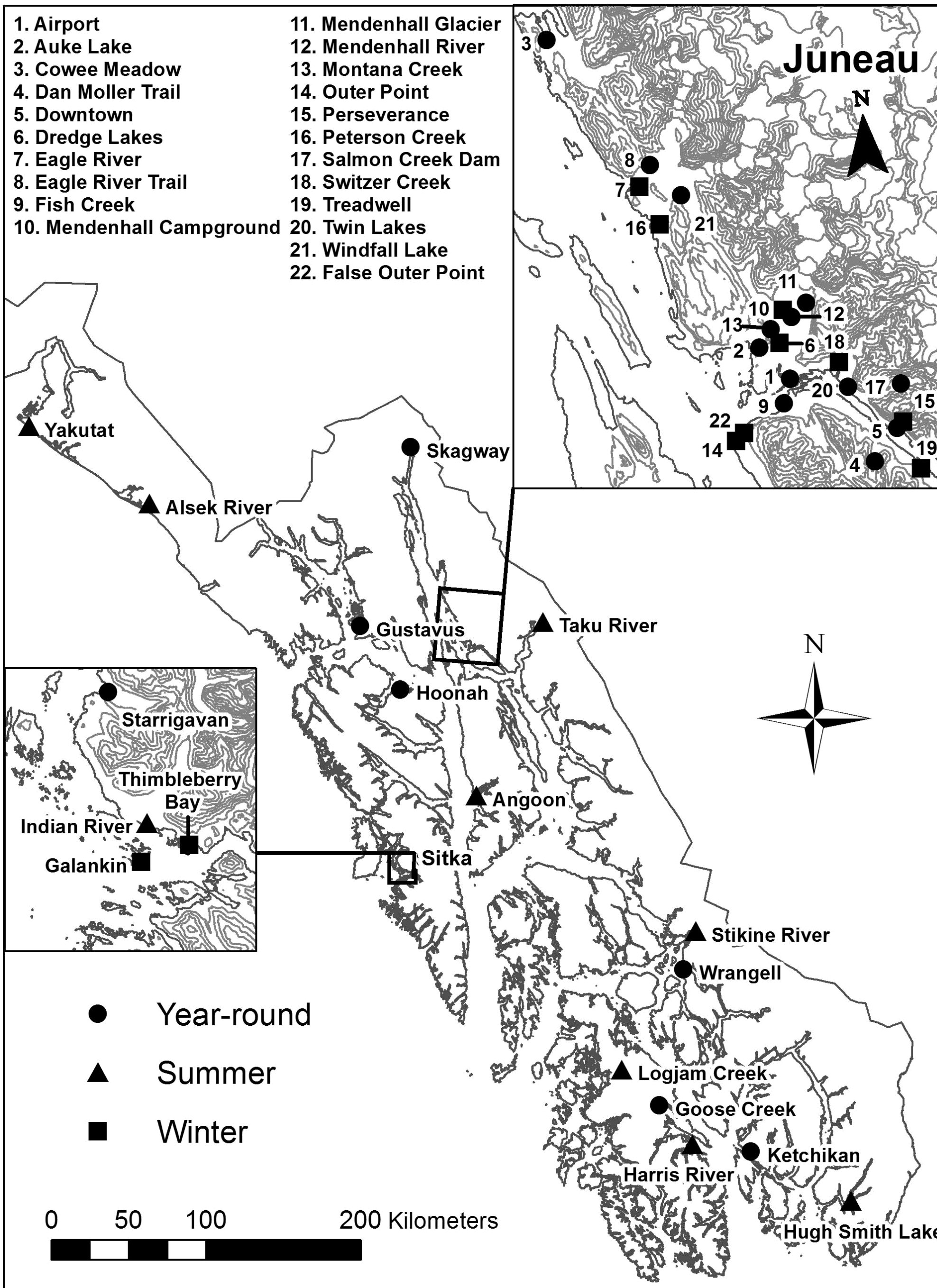

FIGURE 1. Sixteen locations in Southeast Alaska monitored for bat activity during March 2011–September 2013. Two locations had multiple sampling sites (insets: Juneau and Sitka), for a total of 40 acoustic monitoring sites. Symbols denote primary monitoring season (summer-active = April–November; winter-hibernation = December–March).

TABLE 1. Total nights of monitoring, number of confirmed and probable LACI (Hoary Bat), LANO (Silver-haired Bat), LANO-EPFU (Silver-haired Bat-Big Brown Bat), and LowF (Hoary Bat, Silver-haired Bat, or Big Brown Bat) call files for 40 acoustic monitoring sites in Southeast Alaska.

Site	Total Nights of Monitoring	Confirmed LACI	Probable LACI	LANO	LANO-EPFU	LowF	Total Calls
JUNEAU SITES							
Airport	882	1	1	42	133	0	177
Auke Lake	836	5	4	31	143	9	192
Cowee Meadow	746	1	0	5	51	20	77
Dan Moller Trail	666	0	0	0	6	2	8
Downtown Juneau	426	0	1	1	9	3	14
Dredge Lakes	601	0	0	3	8	0	11
Eagle River	85	0	0	0	0	0	0
Eagle River Trail	736	0	0	2	24	0	26
False Outer Point	23	0	0	0	7	0	7
Fish Creek	933	0	0	57	159	20	236
Mendenhall Campground	92	0	0	0	0	0	0
Mendenhall Glacier	717	0	0	1	64	3	68
Mendenhall River	101	0	0	0	0	0	0
Montana Creek	826	0	0	282	1554	127	1963
Outer Point	185	0	0	2	0	1	3
Perseverance	79	0	0	0	0	0	0
Peterson Creek	102	0	0	0	0	0	0
Salmon Creek Dam	660	0	0	46	96	2	144
Switzer Creek	66	0	0	0	0	0	0
Treadwell	98	0	0	0	0	0	0
Twin Lakes	899	0	0	6	26	2	34
Windfall Lake	580	0	0	21	18	2	41
REGION SITES (MAINLAND)							
Gustavus	501	0	1	0	5	2	8
Hugh Smith Lake	263	0	0	2293	18,928	58	21,279
Skagway	432	0	0	0	20	1	21
Yakutat	167	4	0	0	1	0	5
REGION SITES (ALEXANDER ARCHIPELAGO)							
Angoon (Admiralty)	239	0	0	20	24	0	44
Goose Creek (Prince of Wales)	595	0	0	11	33	0	44
Harris River (Prince of Wales)	197	0	0	2	1	0	3
Hoonah (Chichagof)	514	14	102	1	3	1	121
Ketchikan (Revillagigedo)	377	0	1	5	97	3	106
Logjam Creek (Prince of Wales)	186	0	0	0	0	0	0
Sitka - Galankin (Galankin)	35	0	0	0	0	0	0
Sitka - Indian River (Baranof)	179	0	0	0	0	0	0
Sitka - Starrigavan (Baranof)	314	0	0	4	3	1	8
Sitka - Thimbleberry (Baranof)	73	0	0	0	0	0	0
Wrangell (Wrangell)	430	0	0	133	987	19	1139
REGION SITES (TRANSBOUNDARY RIVER)							
Alsek River	71	0	0	0	0	0	0
Stikine River	128	0	0	106	216	6	328
Taku River	226	0	0	1	39	4	44

making differentiation difficult (Betts 1998). In addition, some Hoary Bat calls overlap those of both Silver-haired Bats and Big Brown Bats (Humboldt State University Bat Lab 2011). However, sequences of calls of Big Brown Bats or Silver-haired Bats have minimum frequencies that are consistent among calls, whereas Hoary Bat sequences tend to show an irregular pattern of minimum frequencies, especially when minimum frequencies are >20 kHz. Call shape between Hoary Bat and Silver-haired Bats or Big Brown Bats also differs. Hoary Bat calls tend to have round bottoms with a slight upward turn at the end, whereas the other 2 species tend to have a downward turn or no curvature at the end of the call and may display an abrupt change in slope mid-way through the call (CLL, unpubl. data).

There exists at least 1 diagnostic call type for each species, allowing us to identify a subset of high-quality calls to the species level. Sequences of calls with consistent minimum frequencies ≥20 and <23 kHz are diagnostic for Big Brown Bats in this possible species assemblage (CLL, unpubl. data), as are calls with a maximum frequency >65 kHz (Humboldt State University Bat Lab 2011). Flat calls (<5 octaves/s) at ≥25 kHz are diagnostic of Silver-haired Bats (Humboldt State University Bat Lab 2011, CLL, unpubl. data). Sequences of narrow bandwidth calls with a duration <30 ms and minimum frequencies <20 kHz are diagnostic of Hoary Bats (Humboldt State University Bat Lab 2011). High quality calls meeting these criteria were classified as confirmed Hoary Bat calls; poor quality or noisy calls meeting these criteria were classified as probable Hoary Bat calls. Although Northern Flying Squirrels (*Glaucomys sabrinus*) can produce echolocation calls in the 15–20 kHz range (Gilley 2013), duration of their echolocation calls (pulses) is significantly longer with mean pulse duration 128 ± 9 (SD) ms (Gilley 2013). Broad bandwidth call sequences with fluctuating minimum frequencies at 20 to 30 kHz are also diagnostic for Hoary Bats (Nagorsen and others 2014); however, because these calls may be difficult to distinguish from LANO-EPFU when noise, echoes, or multiple bats are present, they were classified as probable Hoary Bat calls. Call sequences with uniform minimum frequencies ≥23 kHz that lacked diagnostic features of Silver-haired Bats or Big Brown Bats were classified as LANO-EPFU. Sequences were not identified beyond ''low frequency bat'' (LowF), when calls were fragmented, <3 calls were recorded, or call features were ambiguous.

RESULTS

We recorded 3001 low frequency bat call files in the Juneau area and 23,150 elsewhere in the region for a total of 26,151 call files; 21,279 call files (81%) were recorded at a single site, Hugh Smith Lake, the southernmost site on the mainland (Table 1). In Juneau, low frequency bats were detected at all sites except for 7 winter-only monitoring sites. Elsewhere in the region, low frequency bats were not detected at 4 island sites (3 Sitka sites and Logjam Creek on Prince of Wales Island) and 1 transboundary river site (Alsek River) (Table 1).

We recorded 25 confirmed Hoary Bat call files at 5 sites in northern Southeast Alaska (Table 1). Four sites were on the mainland, 1 in Yakutat and 3 in Juneau (Airport, Auke Lake, and Cowee Meadow), and 1 site (Hoonah) was on Chichagof Island. The call files and associated metadata from each of the 5 locations have been deposited to the University of Alaska Museum's (UAM) Mammal Collection as observations (UAM:Obs:187–UAM:Obs:191). All confirmed Hoary Bat call sequences were recorded in late August or September. There were 3 distinct waves of confirmed Hoary Bat activity; the first was early in the morning on 20 August 2012 at Auke Lake, when 6 call sequences were detected between 00:42 and 01:58. The 2nd peak was on the night of 5–6 September 2012 at Hoonah, with 14 detections between 23:33 and 00:17. Finally, 4 detections were recorded in Yakutat on 15 September 2013 between 18:56 and 19:23. Single call files were recorded at the Juneau airport on 26 August 2013 and at Cowee Meadow in Juneau on 30 September 2013.

We recorded an additional 110 call files that were classified as probable Hoary Bat. Most of these occurred during the peak of activity in Hoonah on 5–6 September 2012 (n = 102). Five call files were recorded at 3 sites in Juneau on the night of 19–20 August 2012, coinciding with the confirmed activity at Auke Lake. The 1st detection that night was at 21:37 in downtown Juneau, the next 3 were between 00:28 and 01:17 at Auke Lake, and the last detection was at 02:21

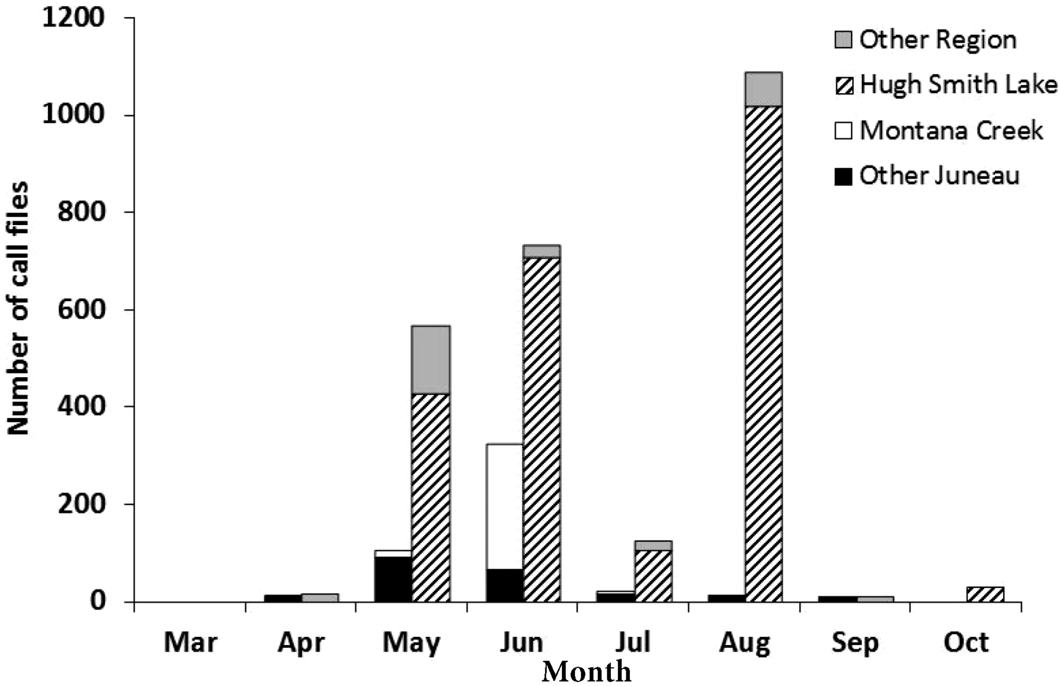

FIGURE 2. Monthly numbers of Silver-haired Bat (*Lasionycteris noctivagans*) call files for sites across Southeast Alaska for all years combined.

at the Juneau airport, suggesting ≥1 Hoary Bats were moving through the area. Probable Hoary Bat calls were also detected at Ketchikan (1 call sequence on 22 April 2012) and Bartlett Cove in Gustavus (1 call sequence on 12 July 2013). No Hoary Bats were detected during the winter months.

We identified 3075 call files at 11 locations (n = 23 sites) as confirmed Silver-haired Bats (Table 1); no call files were identified as confirmed Big Brown Bats. We confirmed the presence of Silver-haired Bats at all but 3 locations on the northern mainland (Skagway, Gustavus, and Yakutat), 1 transboundary river site (Alsek), and 1 location on Prince of Wales Island (Logjam Creek). Silver-haired Bats were detected throughout the summer active season (Fig. 2), but there were only 2 confirmed Silver-haired Bat detections in winter, both at Montana Creek in Juneau in late March. Most (75%) of the confirmed Silver-haired Bat calls were recorded at Hugh Smith Lake (Table 1). Peaks in seasonal activity differed among sites; activity peaked strongly in June at Montana Creek, but was highest in May for all other Juneau sites combined (Fig. 2). Activity at Hugh Smith Lake was bimodal, with a peak in June and a stronger peak in August (Fig. 2); however, there were gaps in monitoring at this site in July during both years (Fig. 4). Activity was highest in May for all other region sites combined (Fig. 2). Because most Silver-haired Bat or Big Brown Bat calls could not be identified to species, we combined LANO and LANO-EPFU calls (hereafter LANO-LANOEPFU) for further examination of activity patterns.

There was considerable variation in both the level and seasonality of LANO-LANOEPFU activity among sites and years. We recorded 1223 LANO-LANOEPFU in Juneau in 2011, 1397 in 2012, and 177 in 2013 (Fig. 3). Activity was highest between mid-May and mid-July in 2011 and 2012, whereas in 2013 activity was low, sporadic, and relatively evenly distributed between mid-April and early September (Fig. 3). Auke Lake was the only site that consistently detected LANO-LANOEPFU during most months in all 3 years of the study, although detections at this site were relatively low, comprising only 6% of the total for Juneau. Most Juneau LANO-LANOEPFU call files in 2011 (84%) and 2012 (58%) were from a single

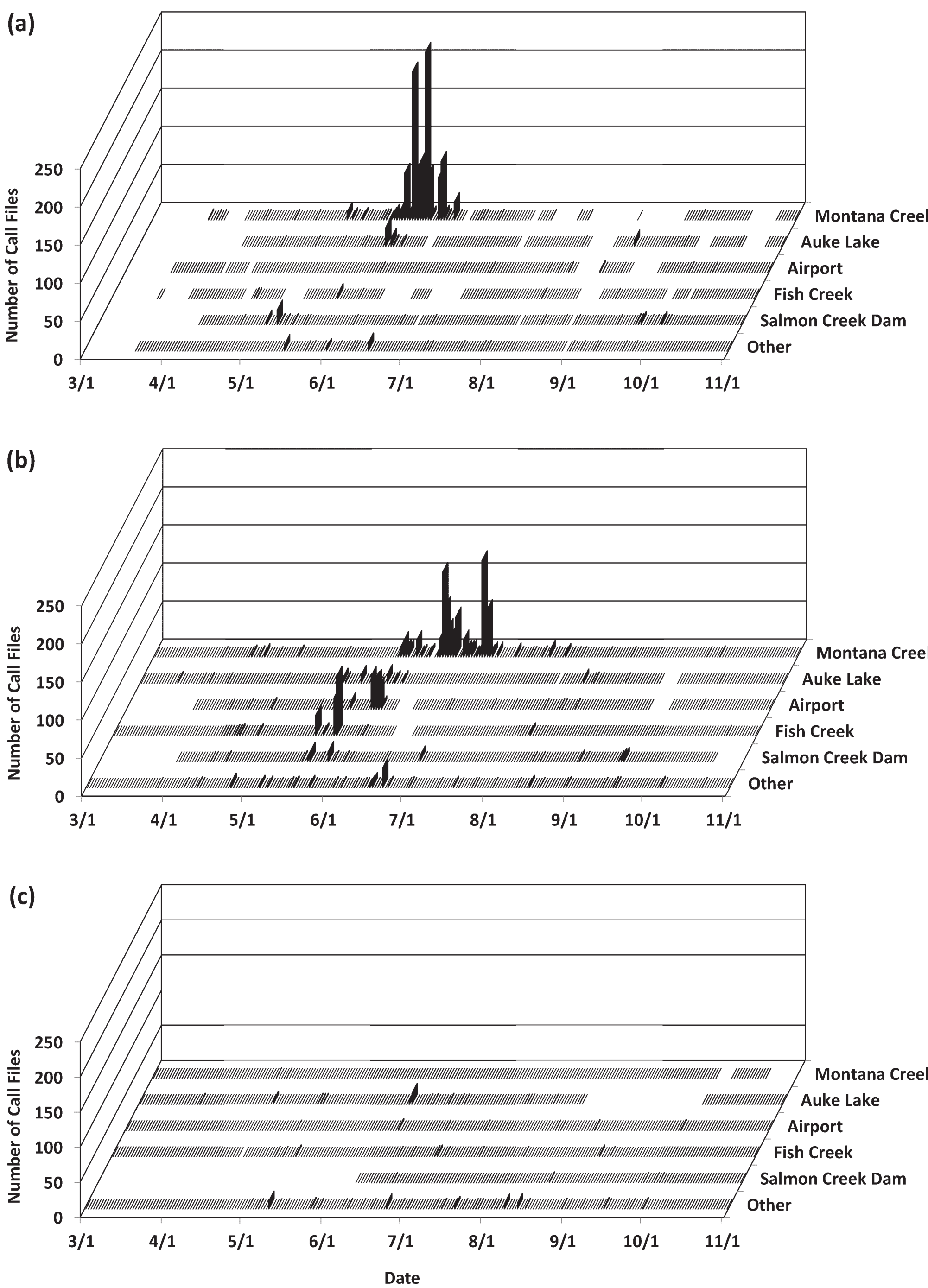

FIGURE 3. Nightly numbers of LANO (Silver-haired Bat) and LANO-EPFU (Silver-haired Bat-Big Brown Bat) call files for sites in Juneau, Alaska in (a) 2011, (b) 2012, and (c) 2013. ''Other'' includes all sites with <100 total call files. Gaps indicate dates when the detector at that site was not operational.

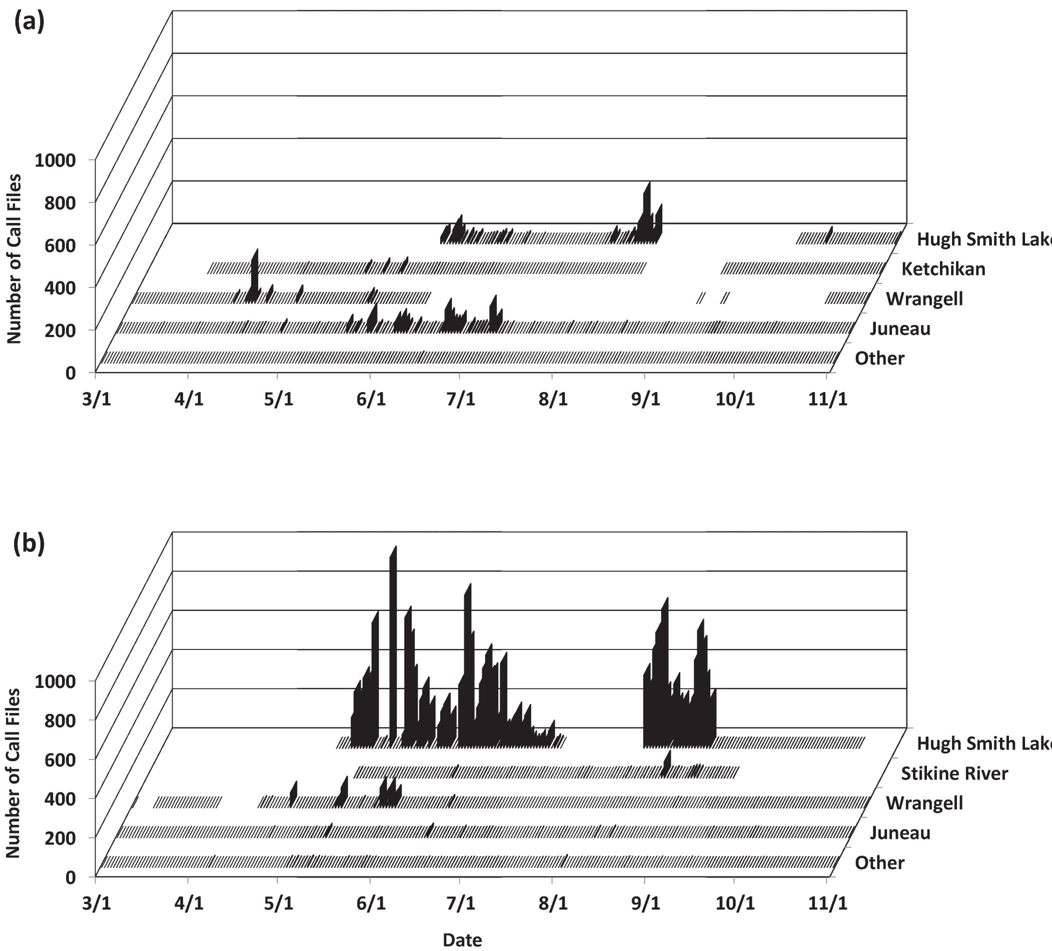

FIGURE 4. Nightly numbers of LANO (Silver-haired Bat) and LANO-EPFU (Silver-haired Bat-Big Brown Bat) call files for sites across Southeast Alaska in (a) 2012 and (b) 2013. ''Other'' includes all sites with <100 total call files and ''Juneau'' includes total call files from all 22 Juneau sites. Gaps indicate dates when the detector at that site was not operational.

site, Montana Creek; only 2 call files (1%) were recorded at this site in 2013 (Fig 3).

Across Southeast Alaska, LANO-LANOEPFU activity decreased from south to north and east to west (Fig. 4). Three locations (Juneau, Wrangell, and Hugh Smith Lake) accounted for 96% of all LANO-LANOEPFU activity in 2012; 2 of those same locations (Wrangell and Hugh Smith Lake) accounted for 97% of all activity in 2013 (Fig. 4). In Wrangell there was a spring (April and May) peak in activity in both years; this was followed by a period of low activity in June and no activity in July in 2013 (the detector was not operational in June and July of 2012; Fig. 4). At the nearby Stikine River site, activity was intermittent and low through early June and consistently low thereafter, with a slight peak in late August (Fig. 4). Ketchikan had an activity pattern similar to Wrangell although overall activity levels were lower (Fig. 4). At Hugh Smith Lake there was a bimodal pattern of activity during both 2012 and 2013, with strong peaks in June and August, although there were gaps in monitoring in July during both years (Fig. 4).

Emergence dates were relatively synchronous within years in Juneau, although the actual dates differed among years. In 2011, 7 Juneau detectors were operational by early April; 3 of the 7 detected their 1st LANO-LANOEPFU on

24 April 2011. In 2012, the first LANO-LANOEPFU were detected during 7–12 April 2012 at half the sites (detectors at half of the remaining sites detected their 1st LANO-LANOEPFU earlier and half later). In 2013, 8 of 11 detectors detected the 1st LANO-LANOEPFU between 2–13 May 2013 (1st detections were earlier at 2 sites and later at 1 site). In the fall, activity at most Juneau sites dropped off by September or October. In 2011, activity at 6 of 7 Juneau sites ceased between 9 September and 11 October; activity at Auke Lake continued into December. In 2012, the last low frequency bat was detected at 4 sites during 3–8 October 2012, at 2 sites during 21–22 October 2012, and at 2 sites during 15–22 November 2012. Activity ceased by 1 October in 2013 at all sites except for False Outer Point.

LANO-EPFU were recorded in all months of the year, although only 1 LANO-EPFU was detected at a region site in winter; that call sequence was recorded at Starrigavan Creek in Sitka on 9 March 2012. By contrast, LANO-EPFU were recorded throughout the winter months in Juneau. At Auke Lake, LANO-EPFU were detected during all 3 winters of the study and in every month except February. At Montana Creek, LANO-EPFU were detected over 2 winters; 1 on 7 February 2012 and 3 in March 2011. At Eagle River Trail, LANO-EPFU were detected in January and March 2012, and at False Outer Point, 2 LANO-EPFU were detected in December 2013. Corresponding temperatures at the times that the calls were recorded ranged from 0.58 to 1.61°C in December, −2.65°C in January, −1.96 to 0.58°C in February, and −0.43 to 2.18°C in March. Flights of low frequency bats were also recorded in Juneau in November (2 LowF at Auke Lake, 1 LANO–EPFU in Downtown Juneau, and 5 LANO-EPFU at False Outer Point late in the month); corresponding temperatures ranged from −0.97 to 4.30°C. There were also 6 LANO-EPFU call sequences recorded at Hugh Smith Lake on 1 November 2012; temperatures ranged from 5.56 to 6.57°C.

DISCUSSION

Our study is the first to document the presence of Hoary Bats in Alaska and represents the northernmost report of Hoary Bat migratory activity along the Pacific Coast. Although Hoary Bats have long been hypothesized to be long-distance migrants, the timing of migratory activity and migration routes have been difficult to study directly. Using occurrence records, Cryan (2003) inferred a general pattern of Hoary Bats moving coastward in autumn and hypothesized that some female Hoary Bats may migrate to their wintering grounds in California by skirting the Rocky Mountains to the north. Stable isotope analysis of individual Hoary Bats confirmed both southward and coastward movements of this species in autumn and raised the possibility that some Hoary Bats may migrate to coastal regions to hibernate rather than continuing to follow coastlines southward (Cryan and others 2014). Cryan and Brown (2007) observed autumn migratory activity of Hoary Bats at a remote island off the California coast between late August and the end of October, with a peak in mid-September. Similarly, Nagorsen and others (2014) documented multiple peaks of Hoary Bat activity throughout the month of September at 2 sites in the Coast Mountains of British Columbia. The timing of activity in both studies supports the hypothesis of a coastward migration. Baerwald and Barclay (2011) also documented waves of Hoary Bats moving through southwestern Alberta; the timing of that peak occurred in mid-August, almost a month earlier than on the Pacific Coast, which is also consistent with a coastward migration. All of the Hoary Bat call sequences we documented, and most of the probable Hoary Bat sequences, were associated with 3 peaks of activity that occurred in 3 separate locations in late August and September, suggesting this species migrates through or into Southeast Alaska as opposed to breeding there. There is some evidence that tree-roosting bat species such as Hoary Bats migrate at high elevations in autumn (Johnson and others 2011). If this is true, it may explain the higher levels of activity detected at the high-elevation sites in British Columbia (Nagorsen and others 2014) relative to our low-elevation sites in Southeast Alaska.

We detected Silver-haired Bat activity throughout the summer active season, indicating that Silver-haired Bats are resident in Southeast Alaska. The low levels of activity at most sites and absence of confirmed Silver-haired Bat activity at the most northern sites suggest that the species occurs at low densities and probably reaches the northern limits of its coastal distribution in Southeast Alaska. It is unclear whether Silver-haired Bats are breeding throughout their range in Southeast Alaska, but the relatively high June activity levels observed at Hugh Smith Lake and Montana Creek in Juneau suggest the possible presence of nearby maternity roosts and the potential for breeding in at least some areas of the region. The long season of LANO-EPFU activity (April–November) at Hugh Smith Lake suggests it could be an area for fall breeding, raising young, and nearby hibernation.

The Silver-haired Bat has typically been described as a migratory species across much of its North American range (Kunz 1982), but winter records and relatively even sex ratios in southern British Columbia (Schowalter and others 1978; Nagorsen and others 1993; Cryan 2003) and the Pacific Northwest (Izor 1979; Cryan 2003; Falxa 2007) suggest that Silver-haired Bats are either year-round residents in some locations, or make a shorter distance migration. If bats from interior British Columbia were migrating to Alaska to hibernate in the milder coastal conditions, we would expect to see peaks of activity in spring and fall at our transboundary river monitoring sites. In Washington, spring migration of Silver-haired Bats occurs from late April to late May and autumn migration from late August to late September (Hayes and Wiles 2013). Our sites were not established until early May on the Stikine River and late May on the Taku River, which may have been too late to detect spring migratory activity. In 2013, activity at both sites peaked in August, supporting the idea that some LANO-EPFU migrate between the interior and coast for the winter, although activity levels were low, especially on the Taku. At both sites, the rivers and associated floodplains were relatively wide at the spots where the detectors were located and it is possible that many migrating bats were out of range of the detectors. It is also possible that migrating bats are not restricted to following river corridors; trekkers in Wrangell-St. Elias National Park (M Terwiliger, US National Park Service, pers. comm.) and in southwest Yukon (Slough and Jung 2008) have reported finding dead bats on glaciers, suggesting bats may traverse the Coast Ranges by following glaciers or mountain ridges.

Given that Silver-haired Bats, but not Big Brown Bats, have been detected both physically and acoustically in Southeast Alaska, most LANO-EPFU were likely Silver-haired Bats. Assuming that this is true, both the temporal and spatial distribution of Silver-haired Bat (LANO-LANOEPFU) across the region lends further support to the idea that interior bats are migrating to Southeast Alaska to overwinter. Activity was highest at locations on or near the mainland and close to transboundary rivers (Juneau, Wrangell, and Hugh Smith Lake; Fig. 1) and lowest along the outer coast. Although the sites with the highest activity (Montana Creek and Hugh Smith Lake) showed peaks of activity in June, suggesting potential reproduction, all other sites with >100 detections showed distinct waves of activity in April (Wrangell), May (Wrangell, Ketchikan, Auke Lake Airport, Fish Creek, and Salmon Creek Dam), and August (Stikine River and Salmon Creek Dam), with little or no activity during the intervening summer breeding season (Fig. 3, Fig. 4). The only site with waves of activity during both spring and autumn was Salmon Creek Dam, the highest elevation (369 m) site that we monitored. Our observations are consistent with a pattern of low-elevation migration during spring (when activity peaked at most of our sites) and high-elevation migration during autumn that has been hypothesized for migratory tree bats in other parts of their range (Johnson and others 2011).

We provide the 1st records of Silver-haired Bat or Big Brown Bat flights in late fall and winter (November–March) in Southeast Alaska, confirming that one or both of these species is overwintering in this region. Low frequency winter bat activity was recorded only in Juneau and Sitka. Detections at the same sites in multiple years (Auke Lake and Montana Creek) indicate that Silver-haired Bats regularly overwinter nearby. Those sites differed in their topography, forest cover, and type of water feature, suggesting Silver-haired Bats are flexible in their choice of overwintering roosts. What features are being used as hibernacula will require targeted investigation.

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APPENDIX

Site names, locations, and habitat for 40 acoustic monitoring sites in Southeast Alaska. The dates of monitoring (Dates columns) are given by calendar year, along with the number of nights during the summer active/winter hibernation seasons when the detectors were operational (Nights columns). Island names are given in parentheses following the site name for Alexander Archipelago sites.

				2011		2012		2013	
	Latitude	Longitude	Habitat	Dates	Nights	Dates	Nights	Dates	Nights
JUNEAU SITES									
Airport	58.382	−134.583	pond	3/18-12/18	220/32	1/18-12/31	237/57	1/1-12/31	235/107
Auke Lake	58.381	−134.629	lake	4/9-12/25	208/14	1/2-12/31	265/114	1/1-11/14	183/83
Cowee Meadow	58.656	−134.941	wetland	3/21-12/31	182/40	1/1-12/3	241/94	3/31-11/5	219/1
Dan Moller Trail	58.276	−134.456	forest/trail	4/8-12/31	190/31	1/1-12/11	245/67	5/29-11/6	156/0
Downtown Juneau	58.303	−134.416	residential	3/23-12/31	83/31	1/1-11/20	257/86		
Dredge Lakes	58.405	−134.574	lake	7/2-12/27	95/21	1/5-11/27	230/87	4/21-11/5	199/0
Eagle River	58.525	−134.805	river			12/14-12/31	0/18	1/1-3/26	0/67
Eagle River Trail	58.543	−134.786	wetland	9/6-12/31	86/31	1/1-12/31	236/114	1/1-11/9	213/79
False Outer Point	58.308	−134.672	cliff/beach					11/25-12/17	6/17
Fish Creek	58.332	−134.596	pond	3/18-12/22	197/25	1/6-12/31	268/115	1/1-12/31	243/116
Mendenhall Campground	58.412	−134.586	wetland			12/13-12/31	0/17	1/1-3/28	0/75
Mendenhall Glacier	58.416	−134.548	pond	4/23-12/31	188/21	1/1-12/2	224/77	3/21-11/10	211/11
Mendenhall River	58.384	−134.595	river			12/7-12/31	0/17	1/1-3/27	0/84
Montana Creek	58.396	−134.609	creek	3/22-12/25	182/32	1/5-12/31	272/90	1/1-10/21	199/82
Outer Point	58.302	−134.678	beach			9/25-12/31	13/18	1/1-12/31	70/84
Perseverence	58.308	−134.405	forest gap			2/24-5/20	73/29		
Peterson Creek	58.492	−134.776	creek			12/14-12/31	0/18	1/2-3/26	0/84
Salmon Creek Dam	58.341	−134.404	reservoir	4/8-12/31	234/26	1/1-12/14	221/30	6/7-11/4	151/0
Switzer Creek	58.363	−134.501	creek			12/7-12/28	0/7	2/20-5/8	33/26
Treadwell	58.267	−134.381	forest edge			12/10-12/31	0/17	1/1-3/25	0/81
Twin Lakes	58.342	−134.490	residential	3/20-12/19	223/31	1/2-12/29	269/119	1/12-11/15	229/59
Windfall Lake	58.516	−134.739	wetland	6/2-6/27	26/0	3/15-12/24	250/37	1/25-11/16	218/66
Juneau – Total monitoring nights					2114/335		3301/1228		2565/1122
REGION SITES (MAINLAND)									
Gustavus	58.456	−135.867	forest/beach			3/31-12/31	190/32	1/1-11/2	205/75
Hugh Smith Lake	55.097	−130.707	lake			6/2-11/8	114/0	4/28-10/20	149/0
Skagway	59.503	−135.358	wetland			2/23-11/18	239/38	3/5-10/5	167/19
Yakutat	59.496	−139.725	beach					4/11-11/16	167/0
Mainland – Total monitoring nights							543/70		688/94
REGION SITES (ALEXANDER ARCHIPELAGO)									
Angoon (Admiralty)	57.459	−134.521	reservoir			3/21-4/29	40/85	3/30-11/25	197/85
Goose Creek (POW)	55.688	−132.635	creek			2/7-12/31	237/53	1/1-11/30	219/0

APPENDIX. Continued.

				2011		2012		2013	
	Latitude	Longitude	Habitat	Dates	Nights	Dates	Nights	Dates	Nights
Harris River (POW)	55.458	−132.801	river			2/8-9/25	175/31		0/48
Hoonah (Chichagof)	58.099	−135.393	wetland			4/13-12/31	217/39	2/12-11/4	218/52
Ketchikan (Revillagigedo)	55.407	−131.705	wetland			2/8-12/23	200/30	1/11-11/21	97/0
Logjam Creek (POW)	55.897	−133.017	creek			3/2-9/30	186/28		0/7
Sitka-Galankin (Galankin)	57.027	−135.323	forest gap			2/8-3/26	6/0		0/26
Sitka-Indian River (Baranof)	57.050	−135.318	river				0/102	6/28-12/31	153/63
Sitka-Starrigavan (Baranof)	57.130	−135.365	creek	2/10-31	0/22	1/1-12/31	147/73	1/1-4/12	11/0
Sitka-Thimbleberry (Baranof)	57.038	−135.270	forest/beach			1/5-3/23	23/52		0/40
Wrangell (Wrangell)	56.475	−132.361	wetland			2/9-11/27	139/0	1/2-11/27	230/0
Alexander Archipelago – Total monitoring nights					0/22		1370/493		1125/321
REGION SITES (TRANSBOUNDARY RIVERS)									
Alsek River	59.171	−138.484	river					6/13-9/21	71/0
Stikine River	56.695	−132.223	river					5/9-9/13	128/0
Taku River	58.557	−133.680	river			5/19-9/27	112/1802	5/22-9/13	114/1539
Transboundary River – Total monitoring nights							112/1802		313/1539
Region – Total monitoring nights					0/22		2025/2365		2126/1954